High-Strength Aluminum Casting Alloy for High-Temperature Applications

Project Number: 97-10

Investigator: J.A. Lee/EH23

Purpose

The purpose of this project is to develop a low-cost, castable and high-wear resistance aluminum alloy with 30 percent improvement in fatigue and tensile strength at elevated temperatures (600 °F) using commercial casting practices.

Background

Conventional aluminum casting alloys have been used to the limits of their mechanical properties in many high-temperature applications. For this reason, many aluminum alloys are unable to meet a constant demand for production of castable components such as pistons having higher elevated temperature strength at 500 to 600 °F. Since 1995, MSFC has been working with Ford Motor Company of Dearborn, MI, to develop a new aluminum alloy with dual-use benefits. The goal was to develop a new piston alloy to withstand more heat than a conventional piston, improve gas mileage and produce less air pollution to meet the future automobile legislative requirements for low hydrocarbon exhaust emissions. Although the preliminary results looked very promising, no funding was available in 1996 to continue this work due to recent NASA workforce downsizing and budget constraints. Since March 1997, a 2-year CDDF program with $190.0k funding was approved to continue the alloy development work at MSFC.

Approach

In the first year, it is planned to characterize typical U.S. piston alloys such as A390 and SAE 332 to understand why they tend to drastically lose their strengths at temperatures above 500 °F. Metallurgical analysis will be performed to determine the primary alloy strengthening mechanisms and phases. Next, a new alloy chemistry will be formulated to provide new and stable strengthening phases at high temperatures. Modification of silicon morphology and silicon grain sizes can also improve the alloy's fatigue strength significantly. A preliminary test program for high cycle fatigue and tensile strength at 500 °F shall be performed near the end of the first year. In the second year, casting parameters will be optimized and specification for commercial practices will be developed. High-temperature material properties will be developed at MSFC. If successful, a patent application will be filed near the end of the second year.

Accomplishments

A new and very low cost alloy chemistry was successfully formulated with excellent mechanical properties. A total of 250 pounds of the alloy has been cast into tensile test specimens, using commercial air casting practice with a permanent stainless steel mold. Different casting parameters have been used, and the effects of mold temperature, pouring temperature, degassing conditions, and grain-refining inoculation are being studied. Preliminary test data showed that the new alloy achieved more than 120 percent improvement in tensile strength (22 ksi) at 500 °F than the current state-of-the-art U.S. piston alloy A390 (10 ksi). This new alloy's strength has surpassed the current project's goal of 30 percent improvement by a very large margin, while maintaining the same high-wear resistance, low thermal expansion properties as the A390 alloy.

Planned Future Work

The new alloy's strength can be increased further by the modification of silicon morphology and silicon grain sizes. Preliminary high cycle fatigue and tensile strength at 500 °F shall be tested near the end of the first year. In the second year, optimization and specification of casting parameters for commercial practices will be performed. A high-temperature material properties database will be developed at MSFC. A NASA patent application will be filed toward the end of the second year.

Publications and Patent Applications:

A NASA patent application will be filed within the next 6 to 8 months in FY98.

Funding Summary ($k)

	FY97	FY98	Total
Authorized by letter:	90.0	100.0	190.0
Obligated to date*:	90.0	0.0*	90.0

* Funding for FY98 (100k) will be processed and obligated by the end of December 1997. All work will be done in-house in conjunction with our on-site contractor support (IITRI) for the MSFC Materials & Processes Laboratory.

Status of Investigation

Project approved—February 1997

Estimated completion—November 1998

The project is to be continued in FY98 with the remaining 100k authorized by letter.